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THE WITWATERSRAND GOLD REGION, TRANSVAAL, SOUTH AFRICA, AS SEEN IN RECENT MINING DEVELOPMENTS[1]

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Location.—The name Transvaal is applied to a stretch of country lying north of the Vaal River and south of the Limpopo River. It comprises 106,642 square miles and is bounded on the south by the Orange River Colony and Natal, on the west by Cape Colony and Bechuanaland, on the north by Rhodesia, and on the east by Portuguese East Africa and Swazieland. From the lowlands along the Limpopo River the region rises gradually to the south and southeast, and in the southern part is an elevated plateau rising between five thousand and six thousand feet above the sea. This plateau is an open country, heavily covered with grass, with but few trees, and resembling in many respects some of our western states. It is capped by a low range of hills running about east and west and known as the Witwatersrand, or "white-water-ridge." This range is the divide between the waters of the Vaal and the Limpopo rivers, and in fact is the continental divide in this part of Africa, as the Vaal River runs into the Orange River and thence to the Atlantic, while the Limpopo River empties into the Indian Ocean.

[1] During a recent trip to South Africa the writer spent some time studying the occurrence of gold in the Witwatersrand region of the Transvaal. So much has already been written by others on this subject that it is not intended here to enter into a detailed description of the region, but only to discuss some of the more general features as seen in the light of recent developments.

On the southern slope of this divide, where it drops off toward the Vaal River, are the celebrated gold mines of the Witwatersrand, a name locally abbreviated to the Rand. The mines occur at frequent intervals for some fifty miles in a general east and west direction along the Rand, with the town of Johannesburg about midway along this line, while the ore-bearing formation has been traced even beyond these limits.

History.—Rumors of the gold of Africa have existed from the most remote times, some of them vague and indefinite, but some more specific, and there seems to be reason to believe that many sources of very ancient wealth were located there. Later on the Phoenicians are known to have bartered extensively in it, and the Arabs in the Middle Ages knew of it, and are supposed to have derived great wealth from it. The Portuguese explorers in the early part of the sixteenth century heard of it and made several more or less serious attempts to work it. It is probable, however, that most of the deposits known to them and to the earlier people were in the vast region extending from north of the Witwatersrand up to tropical Africa, though even in the Witwatersrand signs of old gold workings are said to have been found.

It was not, however, until the latter half of the nineteenth century that modern gold mining in the Transvaal was actively begun. In 1845 Von Buch, and some twenty years later Carl Mauch, reported gold in South Africa. It is said to have been discovered on what is now known as the Witwatersrand, or Rand, as early as 1854, but the Boers opposed its exploitation. In 1870 gold was discovered in the Murchison Range in northeastern Transvaal, and in 1873 mining was begun near Lydenburg, somewhat farther south. In 1875 gold was discovered in the DeKaap gold fields in eastern Transvaal, but active work did not begin until some years later. In 1885 the Sheba mine was discovered in the same region and the town of Barberton soon became a noted mining-center. A few years later, however, it was almost abandoned by the rush to the Witwatersrand. Placer gold mining had been carried on there in a small way for some time, but the first "reef" mining was begun in 1884 and 1885, and in 1886 Johannesburg was founded. From the start the industry grew until now the Witwatersrand is the greatest gold-mining district in the world.

Many other gold districts have been discovered in the Transvaal, Rhodesia, Natal, the Portuguese possessions, and other parts of South Africa, but the Witwatersrand still easily maintains its pre-eminence.

Geological relations of the gold deposits.—The gold of the Witwatersrand occurs as an impregnation of certain conglomerate beds which are members of a series of quartzites, conglomerates and slates known as the Witwatersrand system. These strata lie unconformably on

FIG. 1.—Underground photograph at the Nourse-Deep Mine, Witwatersrand District Transvaal, showing dike and faulting in the gold-bearing conglomerate. The speckled rock in the picture indicates the conglomerate.

older rocks known as the Swazieland series and classed by the local geologists as Archaean.[1] The Witwatersrand system has as yet afforded no fossils, so that its exact age is not known, but judging from fossils found in overlying formations, the Witwatersrand rocks are supposed to belong at least as low as the lower part of the Paleozoic and possibly lower in the geological column.

The Witwatersrand system is divided into an upper and a lower series, though there is no unconformity between them, the only dif-

[1] Hatch and Corstorphine, *The Geology of South Africa*, 1895.

ference being that the lower series is composed largely of slates, with quartzites and rarely some thin conglomerates, while the upper series is composed largely of quartzites, with prominent conglomerates and some little slate. Sheets of diabase are interbedded with both the upper and lower series, and diabase dikes cutting the strata transversely are of frequent occurrence (Fig. 1). The whole Witwatersrand system is much faulted and broken, especially at the east and west ends of the district, making estimates of its thickness in some places often very uncertain. It is known to vary considerably in thickness, however, in different parts of the region, being much thicker in the western part of the Witwatersrand than in the eastern part. In the central part of the district the upper and lower series of the system are each about ten thousand feet or possibly somewhat more in thickness, giving an aggregate thickness for the whole system of approximately twenty thousand feet.[1] To the east they are thinner and to the west thicker.

The Upper Witwatersrand series has been divided by the South African geologists into several different formations, each one consisting largely of quartzite but marked by more or less prominent conglomerate beds. These conglomerates are locally known among the miners as "reefs," and the term has been retained in some of the local geological nomenclature. The divisions of the Upper Witwatersrand made by Hatch and Corstorphine[2] are, in a descending order, the Elsburg series, the Kimberley series, the Bird Reef series, the Livingstone Reef series, and the Main Reef series. The gold of the Witwatersrand mines occurs mostly in the Main Reef series, lying as it does at the base of the Upper Witwatersrand and just above the Lower Witwatersrand series. Small quantities of gold have been found elsewhere in the Upper Witwatersrand series, but rarely in paying quantities, though in some places extensive work has been done in search of it. Small quantities of gold have also been found in the Transvaal in other conglomerates than those of the Witwatersrand system, but have not become of great importance. This is

[1] Hatch and Corstorphine, *op. cit.*, pp. 108, 125.

[2] *The Geology of South Africa*, p. 122. Some doubt is expressed by these writers as to whether the Elsburg series belongs to the Upper Witwatersrand or to the overlying Ventersdorp system. This matter, however, is not of great importance in the present discussion, as almost all the profitable mines on the Witwatersrand are in the Main Reef series.

especially true of the conglomerates of the Black Reef series of the Potchefstroom system, which belongs considerably higher up in the geological column than the Witwatersrand system. A number of attempts have been made to work the Black Reef gold, but so far the success has been small, though in a few instances a certain amount of profit is said, at least temporarily, to have been obtained.

Besides its occurrence in conglomerates, gold is found under various other conditions in various places in the Transvaal, but these

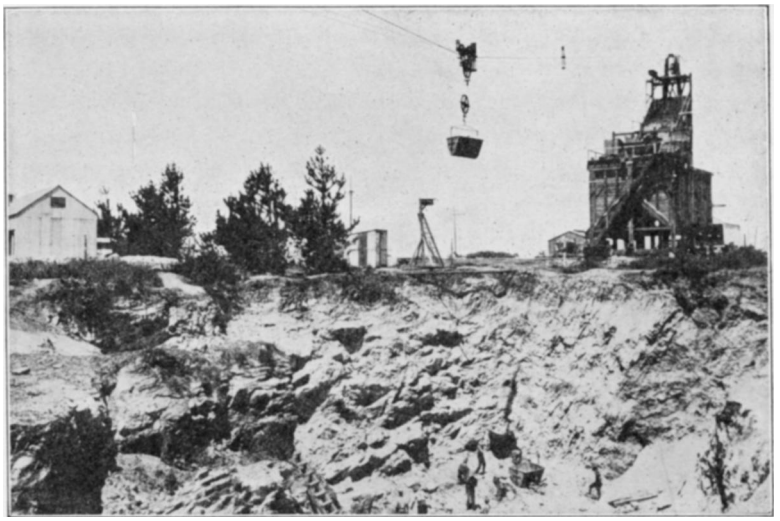


FIG. 2.—Photograph of surface workings in the Crown Reef Mine, Witwatersrand District, Transvaal. The steeply dipping strata underneath the hoisting works on the right-hand side of the picture are the outcrop of the gold-bearing conglomerate.

occurrences are not within the scope of this article. Among them, however, may incidentally be mentioned the auriferous quartz veins in rocks of the Swazieland series in the Barberton region and near Pietersburg; the quartz veins in the rocks of the Dolomite series near Lydenburg and at Malmani; the quartz veins in rocks of the Pretoria series west of Pretoria and west of Krugersdorp as well as elsewhere; the placer workings in many places. The importance of all these occurrences, however, has proved small compared with the gold in the conglomerates of the Main Reef series of the Witwatersrand, the

latter being what has made the Transvaal pre-eminent as a gold producer.

Mode of occurrence of the gold deposits.—The Main Reef series, which, as just stated, carries most of the gold of the Witwatersrand district, contains several gold-bearing conglomerates separated by quartzites of a light-gray or greenish-gray color, dense, brittle, and of either a vitreous or hard sandy structure. More rarely slaty strata occur. On the extreme eastern part of the Rand the conglomerates

FIG. 3.—Underground photograph in the Ferreira-Deep Mine, Witwatersrand District, Transvaal, showing the gold-bearing conglomerate running diagonally across the picture. The speckled rock indicates the conglomerate.

often come close together and are sometimes all within a distance of a few feet of each other. To the west they are scattered over a greater thickness of strata, sometimes one hundred feet or more, measured vertically to the dip. This widening is due chiefly to the widening of the interbedded quartzites, though the conglomerates also increase to some extent. The conglomerate beds vary in number in different places, but certain of them have become especially prominent as gold-producers, the chief ones being known locally as the Main Reef and the South Reef, while the Main Reef Leader and the South Reef

Leader, are usually smaller but often rich beds. Other less important conglomerates are the North Reef, the Middle Reef, etc.

The Main Reef, from which the Main Reef series has received its name, is generally the largest, and ranges from a few feet to probably fifteen feet or more in thickness, though usually not of high grade. It outcrops along a general east and west course throughout the district, and dips in a southerly direction at angles which are often steep near the surface, frequently 80° or more (Fig. 2), and shows a tendency

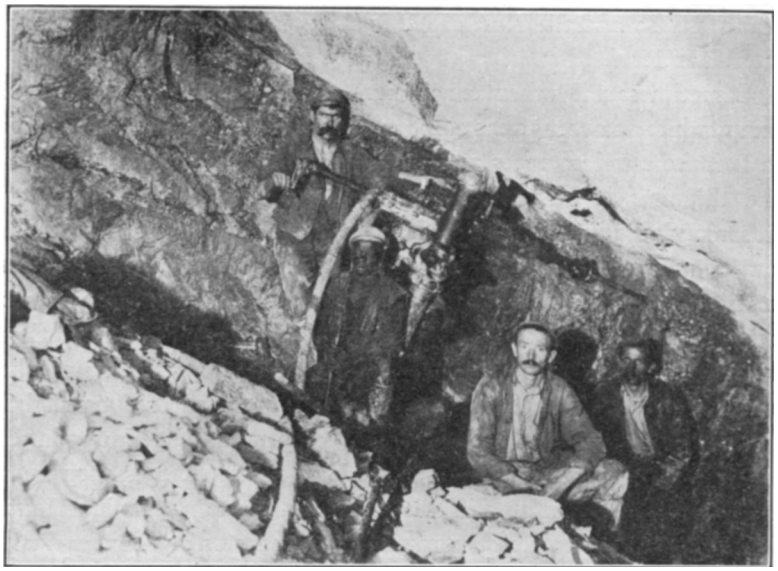


FIG. 4.—Underground photograph in the Jumpers-Deep Mine, Witwatersrand District, Transvaal, showing the gold-bearing conglomerate running diagonally across the picture. The speckled rock indicates the conglomerate.

to flatten in depth, a dip of from 40° down to 20° or less being common at no great depth (Figs. 3, 4, and 5). The South Reef lies to the south of the Main Reef and is separated from it by intervening strata of a thickness of from a few feet to ninety feet or more. It is usually somewhat smaller than the Main Reef but is usually richer. It is parallel to, and shows the same variations in dip as the latter. The Main Reef Leader is a conglomerate bed almost immediately overlying the Main Reef and separated from it by only a few inches to a

few feet of intervening strata; in fact the two sometimes seem to come together. It varies from a few inches to several feet in thickness, but is usually thin, though often rich in gold. Sometimes, especially on the eastern part of the Witwatersrand district, a very persistent slaty parting occurs between the Main Reef and the Main Reef Leader, and is locally known as "the interbedded dike." Another small conglomerate, the South Reef Leader, lies immediately under the South Reef, and is also often rich in gold. The Middle Reef is a very low-grade body of conglomerate ore lying between the Main and South Reefs; and the North Reef is also a low-grade bed lying below the Main Reef.[1]

Sometimes still other conglomerate beds than those mentioned occur, while at other times some of the beds mentioned are wanting. In fact the conglomerates are more or less lenticular strata, widening and thinning at intervals, and sometimes disappearing altogether. In some places two or more beds may blend into one, or any one bed may be split up into two or more beds separated by quartzite; so that in different localities, a different number of conglomerates may be found, and those that have been described above are simply those that are usually the most continuously represented. Sometimes what seem to be the same conglomerates change their positions slightly in the associated strata and are a little higher or a little lower in one place than in another, while sometimes the formation is very much faulted, so that it is often difficult to correlate certain beds in different places. On the whole, however, the conglomerates, as compared with conglomerates elsewhere, may be said to be remarkably continuous over long distances, and this feature of the ore bodies has been one of the chief factors in the wonderful development of the mining operations of the region.

Though the conglomerates mentioned all carry gold, yet the quantity varies considerably in the different beds and even in different places in the same bed. The main Reef, though large, is generally of rather low grade, but it is worked in many places at a good profit. The South Reef and the Leaders are usually of higher

[1] Some of the reefs mentioned here are sometimes known by different names in different parts of the district, but the names given above are those most commonly used.

grade, one or both of the Leaders often being of much better grade than either the Main or South Reef. Though the conglomerates carry most of the gold, in fact all the gold that is mined in the Main Reef series, yet small quantities have been found in some of the quartzites.

The gold-bearing rocks of the Witwatersrand district, dipping, as they do, in a southerly direction, occupy the northerly side of a synclinal fold and come to the surface again in the Heidelberg dis-

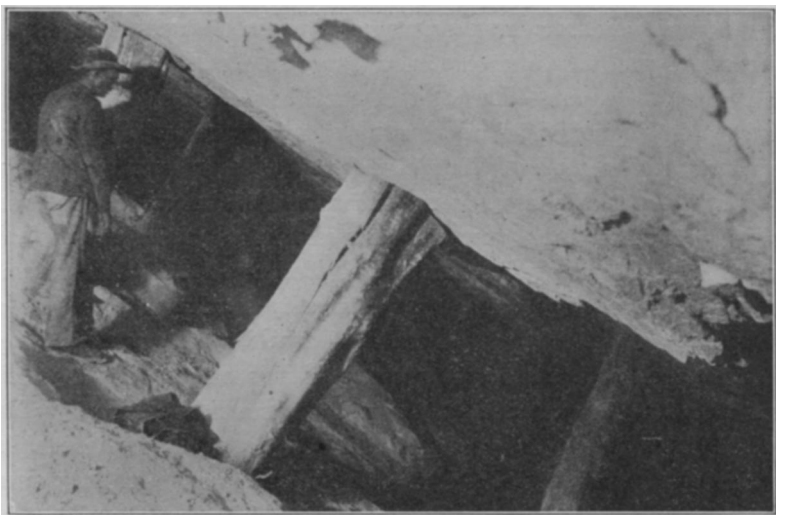


FIG. 5.—Underground photograph at the Durban-Roudepoort-Deep Mine, Witwatersrand District, Transvaal, showing old workings from which the ore has been removed.

trict, some thirty miles southeast of Johannesburg, and on the Vaal River still farther south. More or less gold mining has been carried on in these more southerly districts, but much less extensively than in the Witwatersrand district. On the Witwatersrand the gold formation can be traced along its strike for over sixty miles, and at either end it disappears beneath younger strata. The claim is made, however, that it has been traced with the assistance of borings for over one hundred and sixty miles, and that there is more or less evidence of its extent, though interrupted by faults and covered by more recent strata, for over three hundred miles. So far, however,

none of the outlying districts have become very great producers, while even in the Witwatersrand district it is in only certain parts that highly remunerative results have been obtained. The conglomerates seem to be richest in the central part of the district, and to decrease in value on the east and the west ends. A large percentage of the gold comes from the mines along some twenty-five or thirty miles of the central part of the district, but for a distance of some fifty miles, east and west, there are scattered considerably over a hundred mines. Such a record, both for the number of mines in a given distance on one deposit, and for the percentage of profitable ones among this number, is probably unprecedented anywhere else.

Nature of the ore.—The ores of the Witwatersrand district consist, as already stated, of conglomerates impregnated with gold, and are frequently known by the Boer term "banket." The conglomerates, in their general character, do not differ from many conglomerates in other parts of the world except in their content of gold. The pebbles are well rounded and vary from a small fraction of an inch to several inches in diameter, most of them probably ranging from about a quarter of an inch to about an inch and a half or two inches. They are imbedded in a sandy matrix cemented by secondary silica, which knits them into a solid mass, and often forms small lenses, or irregular bodies of quartz, in the conglomerate. The rock thus cemented is massive and compact, and when broken the fracture often passes through the pebbles as readily as around them. Iron pyrites and marcasite are abundant, and a greenish chloritic or sericitic material often occurs encircling the pebbles and impregnating the matrix. Flakes of muscovite are not uncommon, and under the microscope other minerals, including rutile, zircon, magnetite, corundum, tourmaline, etc., are to be seen.[1]

The pebbles are mostly of a transparent, white, or smoky character, while more rarely some have the appearance of chalcedony, jasper, or chert. Sometimes fragments of quartzite and slate occur in the conglomerate, but they are few as compared with the quartz pebbles. In some places it is found that the coarser the pebbles, the richer the conglomerate in gold, but this does not always hold good, and sometimes the finer conglomerates are the richer. All the Witwatersrand ores are more or less impregnated with iron sulphides, pyrite

[1] Hatch and Corstorphine, *op. cit.*, p. 136.

and marcasite, which vary somewhat in amount in different places. Though the sulphides are usually abundant where the ore is rich in gold, yet they are also often abundant where the ore carries very little gold, so that the quantity of them is not necessarily an indication of the richness of the ore. They are sometimes very finely disseminated in minute particles, at other times in a coarser condition, generally crystalline, and sometimes in concretionary or radiating nodules. They are generally oxidized for a few hundred feet from the surface, giving the ore a brown, rusty appearance, while at a greater depth the ore assumes a gray or greenish-gray color.

The gold is finely disseminated in the ore and is rarely noticeable to the naked eye, though it can sometimes be seen in thin flakes incrusting the pebbles, or in small particles in the siliceous matrix. The gold is not uniformly distributed through the reefs. There are rich places and poor places, but in spite of this, it may be said that the gold is much less irregular over long distances than in most gold deposits, and in no other part of the world can so many mines be seen on the same ore body.

Most of the ores mined in the Witwatersrand district are of low grade, though bodies of higher-grade ore occur, and more rarely small amounts of very rich ore are found. The value usually varies from a grade too low to work profitably up to about $25 per ton and sometimes to very much more. Under the ordinary conditions existing in the district, ore of $6 per ton is about as low-grade material as it pays to work, and most of the ore at present being treated ranges from about that value up to $12 or $15 per ton. The average value of the ore mined in the Witwatersrand district in the year ending June 30, 1905, was from 36.888 to 37.123 shillings,[1] or a little less than $9 per ton.

In the early days only the higher-grade ores were worked, but with the increased facilities for mining and milling, the cost was diminished, and the tendency is, therefore, to save the lower-grade ores which were once thrown away, and to mix them with the higher-grade ores, thus bringing down the average value of the ore treated, but adding to the aggregate amount of gold produced.

The mines vary in depth from a few feet to over 4,000 feet, quite a

[1] "Transvaal Mines Department," *Annual Report of the Government Engineer for the Year Ending June 30, 1905*, p. 8.

number ranging from 1,500 to 2,500 feet, and a few deeper. Those located on the outcrop of the ore are known as "outcrop" mines; the adjoining ones to the south, which are not on the outcrop, but which require a shaft to be sunk to reach the ore on its dip, are known as the "first row of deeps," those next farther south are known as the "second row of deeps," etc. The general term "deep" is thus applied to any of the mines not on the outcrop, and the first, second, third, and even fourth rows of deeps are common terms. The word

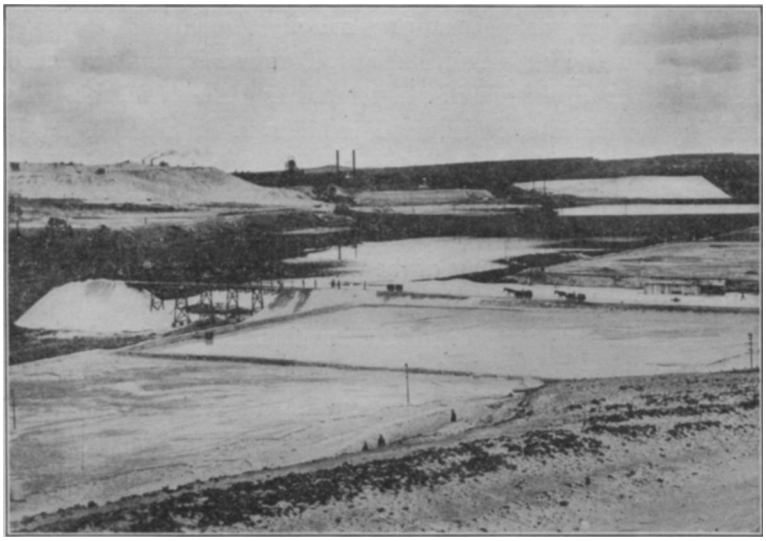


FIG. 6.—Photograph of surface at the Robinson and the Robinson-Deep Mines, Witwatersrand District, Transvaal, showing tailings, dumps, and general surface conditions.

"deep" does not refer in any way to the depth of the mine, but only to the fact that a shaft has to be sunk to reach the ore.

It is not within the scope of this article to discuss the metallurgical treatment of the Witwatersrand ores. It may be said, however, that nowhere else in the world have the mining and treatment of gold ores been carried on with greater efficiency and skill than by the able engineers and metallurgists who have conducted the operations on the Rand; and nowhere has the gold-mining industry been conducted on such a large scale. The ores are treated in large stamp

mills located at or near the mines (Fig. 6), and it is a striking sight to look out from some elevated place and see the long row of immense milling plants following an east and west line as far as the eye can reach along the strike of the ore formation. The ore is partly free milling. About 55 to 65 per cent. of the gold is saved on amalgamating plates, and a large part of the rest is obtained by cyaniding the tailings. Sometimes additional processes to make a more complete extraction are practiced. A well-equipped and well-managed mill, with the present methods, should make a total extraction of probably from 88 to over 90 per cent. of the gold in the ore.

The Witwatersrand district is essentially a region of large quantities of low-grade, yet workable, ore, and there are but few places in the world where gold mining can be carried on so cheaply as there. The ore bodies extend over long distances, and their contents of gold is much less erratic than in most gold mines elsewhere; coal, which is the only available fuel, is found in large quantities in close proximity to the mines, in geological formations overlying the gold-bearing rocks; Kaffir and Chinese labor is cheap, though at present somewhat scarce; the climate is healthy; the mines as a rule are not troubled with any excessive amount of water; the temperature does not increase at a very rapid rate with depth; and the rock is of such a kind that the expense for timber to hold up the underground workings is not great (Fig. 5). Under all these favorable conditions mining can be carried on to very considerable depths so long as the ore holds out, and it is probable that active mining operations will be continued in this region for many years.

The production of the Rand mines from 1884 to June 30, 1906, was over 134,000,000 pounds sterling, or somewhere about $650,000,000, which means practically almost the total production of the Witwatersrand district from the start, as not much gold was obtained there before 1884. The production for 1906, according to the estimates of the Transvaal Chamber of Mines, was 24,579,987 pounds sterling.[1]

It is not intended in the present article to discuss the origin of the Witwatersrand gold ores in detail, but perhaps a few words about the generally accepted ideas on this subject may be well.

[1] These figures for 1906 were kindly furnished to the writer by Mr. W. R. Ingalls, editor of the *Engineering and Mining Journal*, of New York.

The origin of the conglomerates themselves, without reference to the gold in them, was doubtless similar to that of many other conglomerates elsewhere, that is, they were formed by the accumulation of gravel and sand under water near shore. It is probable that they are of marine origin and were laid down along the shore line of some more or less open sea. Later on they were covered by other strata, then elevated into a land area, folded and distorted by the dynamic action to which the region has been subjected, then more or less eroded by atmospheric influences, and eventually left as they are now found.

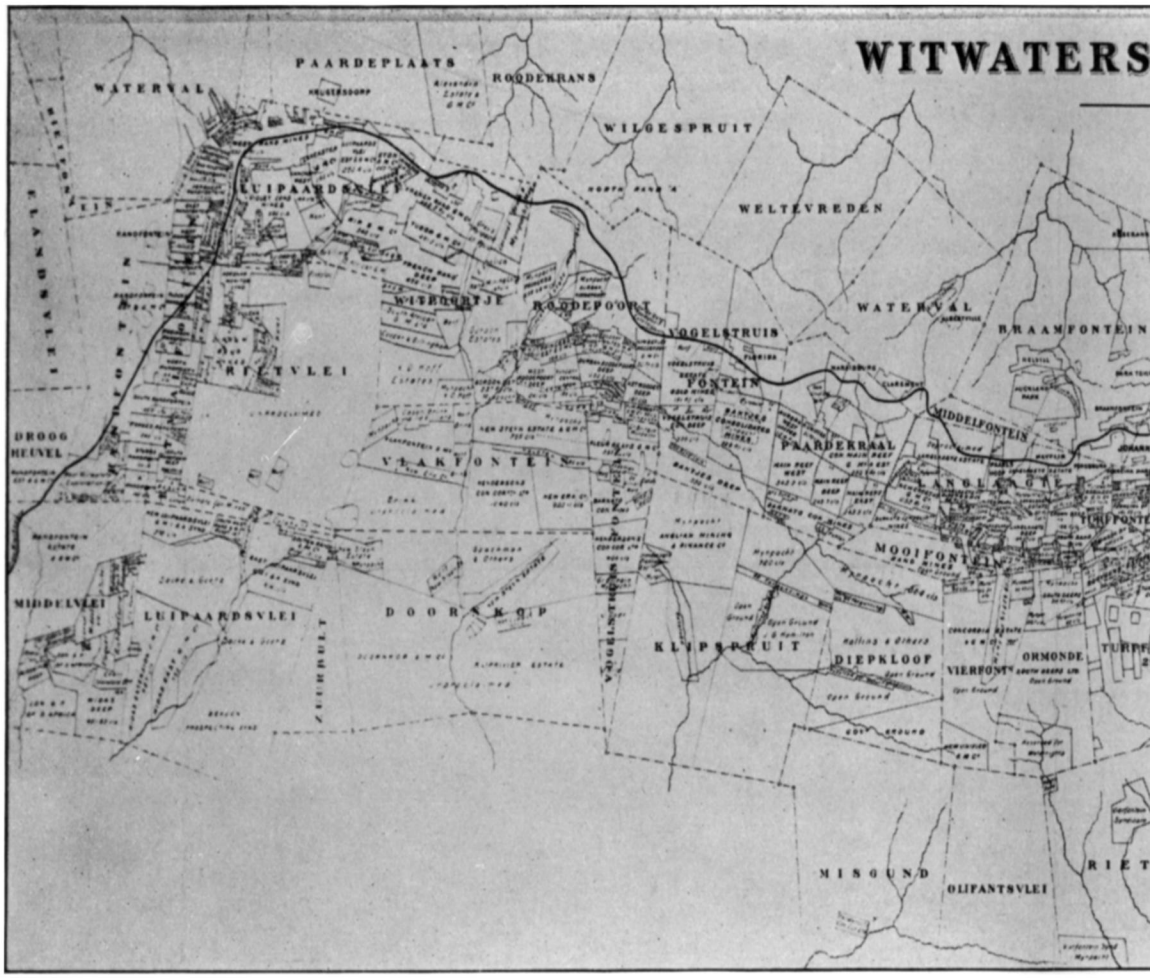
As to the source of the gold in the conglomerates, there has been much more dispute than as to how the latter were formed. Two different theories, among the several that have been advanced on this subject, seem to have received most support. One of them supposes that the gold is all detrital, that it was deposited mechanically with the pebbles of the conglomerates at the same time as these beds were formed, and that it came from the same rocks as the pebbles, or at least from adjacent rocks. In other words, this theory supposes that the gold-bearing conglomerates are simply old placer deposits. The second theory supposes that the gold was brought into the conglomerates after the latter had been formed and probably after they had been elevated into land areas, that the conglomerates simply acted as pervious strata through which gold-bearing solutions found a ready passage, and in which the gold was deposited in much the same way as it is supposed to have been deposited in the fissures containing it in most gold districts.

George F. Becker[1] supports the first theory and believes that the gold was deposited mechanically with the pebbles of the conglomerates and that it came from the erosion of the same land area, though it may have been somewhat changed in position and character by subsequent chemical action. He thinks the conglomerates are of marine origin, and that they are in fact simply marine placers, solidified by the later deposition of secondary silica.

Messrs. Hatch and Corstorphine,[2] on the contrary, believe in the second theory, that is, that the gold was deposited from solutions

[1] "The Witwatersrand Banket, with Notes on Other Gold-Bearing Pudding Stones," *United States Geological Survey, Eighteenth Annual Report, 1896–7*, Part V, "Metallic Products and Coal;" pp. 173–77.

[2] *The Geology of South Africa*, pp. 145, 146.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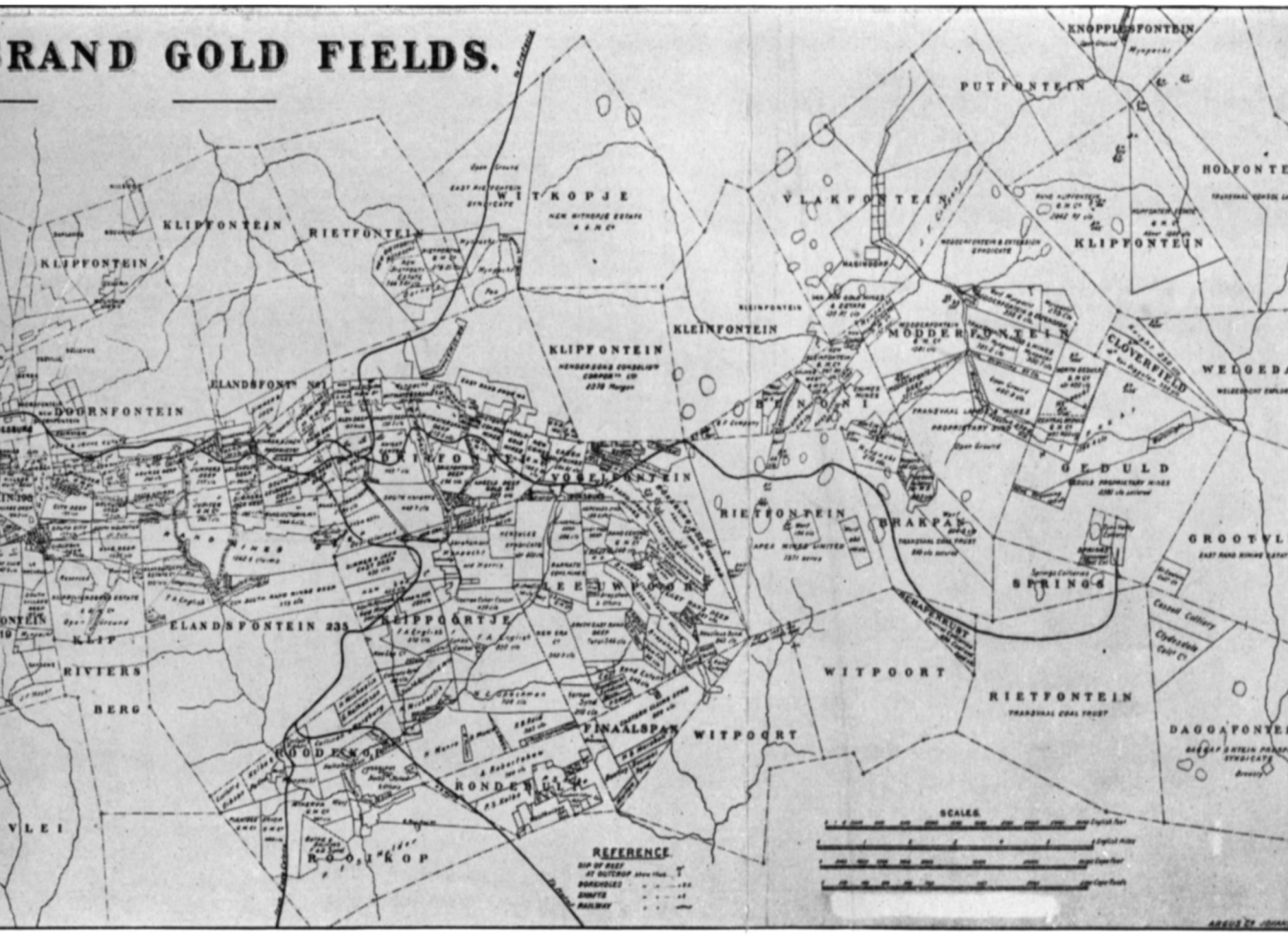
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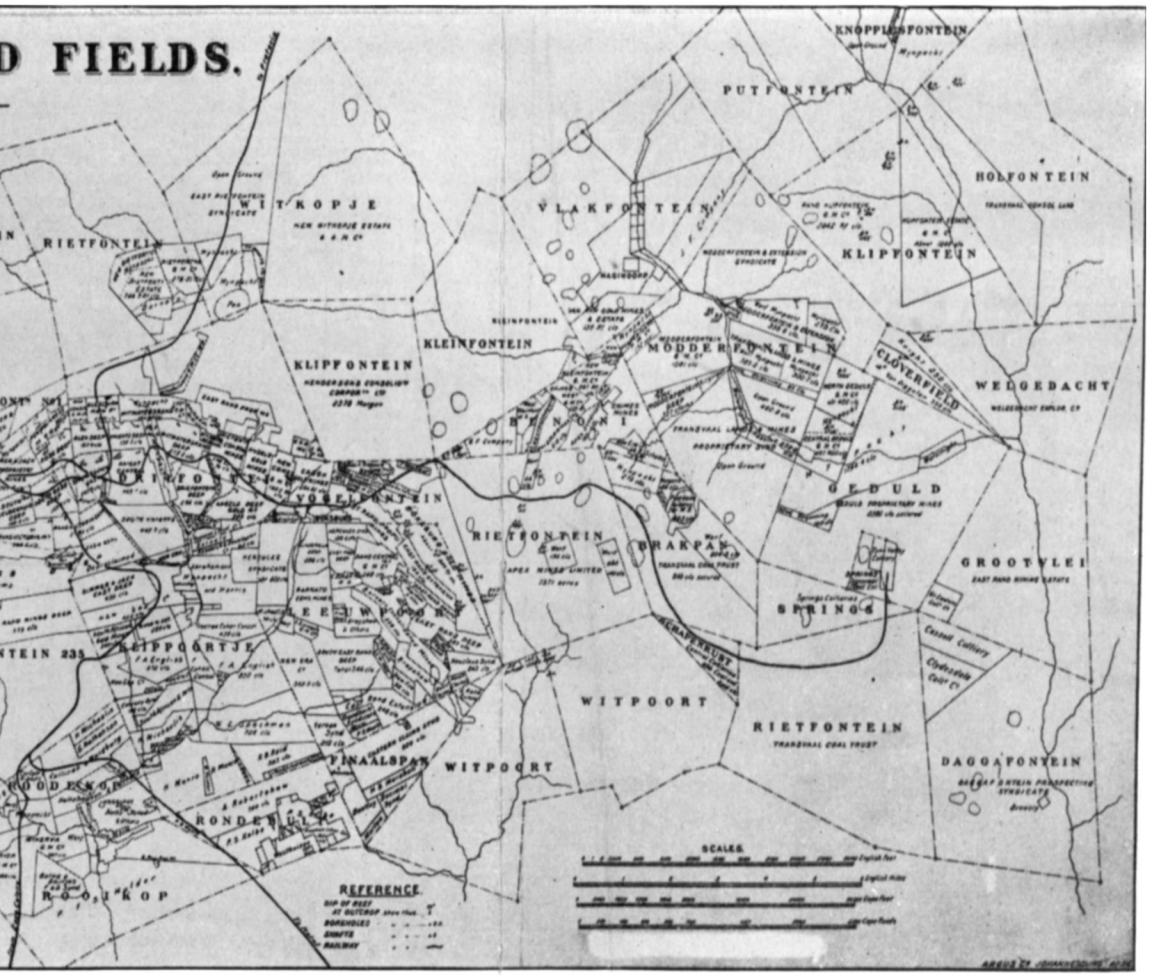
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permeating through the conglomerates after their formation, in much the same manner as gold is deposited in fissures elsewhere. They think that with the gold were also deposited the pyrite, marcasite, and other secondary minerals found in the deposits, including the secondary silica, which has bound the once open pervious conglomerates into solid compact rocks. Most of the geologists and engineers who have been directly connected with the mines in the Witwatersrand district also hold more or less similar beliefs. John Hays Hammond,[1] formerly the noted engineer of the Consolidated Goldfields of South Africa, thinks that a large part of the gold got into the conglomerates in this way, but that some of it was also deposited originally with the conglomerates.

W. H. Penning[2] and L. DeLaunay[3] have suggested that the conglomerates were formed in sea water which was heavily charged with gold and iron sulphide in solution, and that these were deposited in the conglomerates during their formation. This theory has not received much support from others familiar with the region.

[1] "The Genesis of the Witwatersrand Banket," being chap. vi of *The Witwatersrand Goldfields, Banket and Mining Practice*, 1898, by S. J. Truscott.

[2] *Jour. Soc. Arts*, London, Vol. XXXVI, 1888, p. 437.

[3] *Les mines d'or du Transvaal*, 1896.